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STUDIES IN THE DYNAMICAL PREDICTION AND INTERPRETATION OF WEATHER SYSTEMS

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Research Project MIPR ES-7-967
Project No. 6698
Task No. 669802
Work Unit No. 66980201

FINAL REPORT
1 January 1967 - 30 June 1968
October 1968

Contract Monitor: Thomas Keegan, Meteorology Laboratory

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Abstract

Four papers are summarized. The first describes a primitive equations model for use in the tropics. The second and third papers present a method of computing long-wave radiation from water vapor and investigate some consequences of radiation from cloud-top. The fourth paper describes numerical methods of computing 3-dimensional trajectories including diabatic effects.

1. Introduction

This paper summarizes work done under Research Project MIPR ES-7-967, covering the period 1 January 1967 to 30 June 1968. Section 2 describes a primitive equations numerical prediction model with particular applicability to the tropics. This paper could, perhaps, be regarded as the keynote one of this collection. Section 3 presents a method of including long-wave radiation from water vapor in a tropospheric numerical prediction model such as the one outlined in Section 2. Section 4 investigates some synoptic effects of radiation from cloud-top. Section 5 describes numerical methods of computing 3-dimensional trajectories, including diabatic effects of condensation and radiation.

2. An experiment in numerical prediction in equatorial latitudes

(T. N. Krishnamurti)

A multi-level primitive equation model is employed to obtain short range forecasts in equatorial latitudes. The initial field contains the intertropical convergence zone and associated disturbances over the western Pacific Ocean during March 1965. A consistent balance set of equations is used to construct initial fields of pressure, temperature and vertical motion from an observed rotational part of the wind field. It is shown that this procedure, whose validity assumes a small Rossby number, does not yield a realistic structure of the vertical motion.

A short range prediction with the model yields some meaningful solutions in the vicinity of the intertropical convergence zone. During the first 18 hours of prediction an adjustment of the motion and the mass field ensues with gravity-inertia oscillations. A detailed discussion of some dynamical aspects at 24 hours is presented.

An important feature of the model is a parameterization of cumulus convection as a function of large scale moisture convergence. The role of cumulus scale heating in the vicinity of the intertropical convergence zone is explored by performing experiments with and without diabatic heating.

3. On the inclusion of long-wave radiation in a tropospheric numerical prediction model (M. B. Danard).

A simple method of computing long-wave radiative cooling in the troposphere associated with water vapor is described. The procedure may readily be incorporated into a tropospheric numerical prediction model. A subroutine to perform these calculations has been written for Krishnamuti's model described in Section 2. Radiation from ozone and carbon dioxide is not considered. However, influences of arbitrary vertical distributions of cloud and moisture are included.

Average annual cooling rates along a meridional cross-section are calculated for a cloudless atmosphere. The results agree fairly well with the total radiative cooling (long-and short-wave) as given by previous authors except in the lower troposphere at low latitudes. Here short-wave absorption by water vapor is appreciable.

The three-dimensional distribution of long-wave radiative cooling is also computed in a case of a developing cyclone for comparison with that of release of latent heat. The largest cooling occurs at cloud top and can be a significant fraction of the amount of energy released as latent heat in the upper troposphere.

4. Some synoptic effects of long-wave radiation from cloud-top (M. B. Danard) This paper is a continuation of the one described by Danard in Section 3.

Calculations with a synoptic case study show that long-wave radiative cooling tends to reduce the available potential energy, especially in the upper troposphere. Synoptic-scale precipitation amounts resulting from destabilization of cloud by long-wave cooling are computed. These range up to 1.4 mm in 12 hours. This destabilizing effect may be important in explaining the nocturnal maximum of precipitation over the sea. It may also contribute significantly to cyclone development.

5. Numerical methods of computing three-dimensional trajectories for adiabatic and diabatic flows (J. D. Mahlman)

A computer method for objective computation of adiabatic three-dimensional trajectories in the free atmosphere is presented. This trajectory technique was initially designed to provide a check for the diagnostic phase of the numerical model described in Section 2. The computation utilizes an iterative scheme which insures that the final trajectory satisfies the path integrated form of the energy equation.

A test case is run with the program and gives highly satisfactory results in most areas. Some special difficulties arise in regions characterized by either very low wind speeds or strong anticyclonic wind shears.

A procedure for inclusion of diabatic effects is outlined in detail and provides for simultaneous inclusion of long-wave radiative cooling and condensation heating effects. The program developed by Danard (Section 3) is modified to give radiative cooling rates on isentropic surfaces. These results indicate that long wave radiative cooling in the free atmosphere is important enough to include in a diabatic trajectory program along with precipitation effects.

Publications under Research Project MIPR ES-7-967

Danard, M. B., 1968a: On the inclusion of long-wave radiation in a tropospheric numerical prediction model. Sci. Rep. No. 1, AFCRL Res. Proj. MIPR Es-7-967, Naval Postgraduate School, Monterey, Jan. 1968.

Danard, M. B., 1968b: Some synoptic effects of long-wave radiation from cloud-top. Sci. Rep. No. 2, AFCRL Res. Proj. MIPR ES-7-967, Naval Postgraduate School, Monterey, June 1968.

Danard, M. B., T. N. Krishnamurti, and J. D. Mahlman, 1968: Studies in the dynamical prediction and interpretation of weather systems. Final Report, AFCRL Res. Proj. MIPR ES-7-967, Naval Postgraduate School, Monterey, Oct. 1968.

Krishnamurti, T. N., 1968: An experiment in numerical prediction in equatorial latitudes . Sci. Rep. No. 4, AFCRL Res. Proj. MIPR ES-7-967, Naval Postgraduate School, Monterey, Oct. 1968.

Mahlman, J. D., 1968: Numerical methods of computing three-dimensional trajectories for adiabatic and diabatic flows. Sci. Rep. No. 3, AFCRL Res. Proj. MIPR ES-7-967, Naval Postgraduate School, Monterey, July 1968.

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13. ABSTRACT

Four papers are summarized. The first describes a primitive equations model for use in the tropics. The second and third papers present a method for computing long-wave radiation from water vapor and investigate some consequences of radiation from cloud-top. The fourth paper describes numerical methods of computing 3-dimensional trajectories including diabatic effects.

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